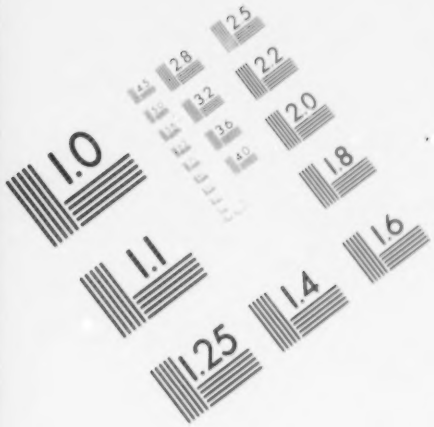

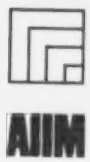

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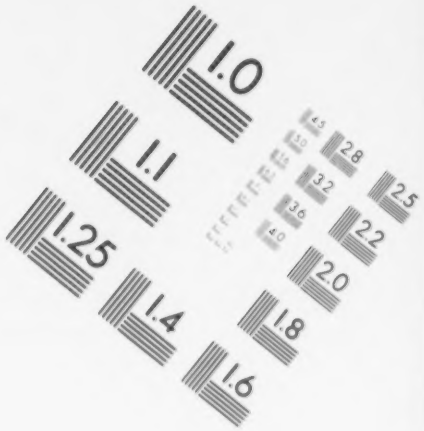

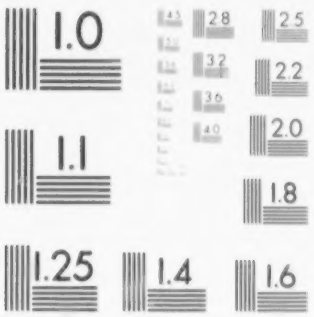

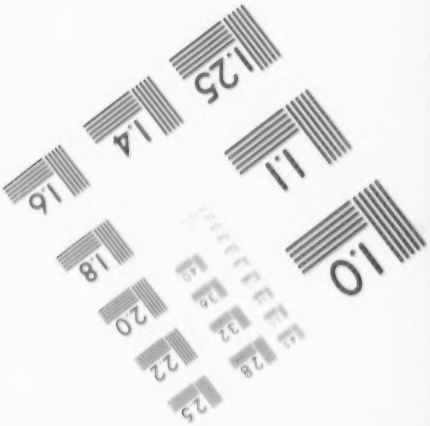

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DOCUMENT RESUME

ED 343 782 SE 052 420

TITLE Science Performance at Grades 8 and 12: Further Analysis of the 1988 Test Results.
INSTITUTION Massachusetts State Dept. of Education, Boston. Massachusetts Educational Assessment Program.
PUB DATE Jan 90
NOTE 35p.
PUB TYPE Reports - Evaluative/Feasibility (142)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Biology; Chemistry; *Cognitive Development; Developmental Stages; Earth Science; Females; Grade 8; Grade 12; *Learning Processes; Physics; Science Education; *Scientific Literacy; Secondary Education; Space Sciences; Vocational Education
IDENTIFIERS *Massachusetts Educational Assessment Program; *Science Achievement

ABSTRACT

The purpose of this report is to examine how well students in Massachusetts are meeting the Goals of Education, as measured by the Massachusetts Education Assessment Program (MEAP). The first section of this report defines various levels of proficiency and then compares different groups within the student population in terms of the percentages attaining each level. The various subgroups include all males and females in grades 8 and 12, students in college prep, general, and vocational-technical programs, and students for whom the highest science courses completed are either chemistry, biology, or physics. The next section describes areas of relative strength and weakness within science of different groups. The sub-areas of science include scientific literacy, life science, earth/space science, and physical science. Cognitive process levels that include knowledge/comprehension and application/higher order and scientific, personal, and technological, societal, and historical contexts are also examined. The report closes with a commentary on improving school science programs. (KR)

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CHAPTER 188

Massachusetts
Educational
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January 1990

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FURTHER ANALYSIS OF THE 1988 TEST RESULTS

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SCIENCE PERFORMANCE

AT GRADES 8 AND 12

FURTHER ANALYSIS OF THE 1988 TEST RESULTS

MASSACHUSETTS EDUCATIONAL ASSESSMENT PROGRAM

MASSACHUSETTS DEPARTMENT OF EDUCATION

1990

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PREFACE

Under the mandates of Chapter 188 of the Acts of 1985, the Massachusetts Educational Assessment Program tests biennially all students at three grade levels in major curriculum areas. The assessment is designed to produce school, district, and statewide results for the purposes of accountability and program improvement. In 1985-86, third, seventh, and eleventh grade students were tested in reading, mathematics, and science. In 1987-88, fourth, eighth, and twelfth graders were tested in the same subjects plus social studies. Testing in these same grades and subjects will be taking place during the 1989-90 school year.

The most important product of the testing program is the MEAP *Educational Assessment Report* produced for every school in the Commonwealth. This document presents, among other things, each school's results on the different tests and subtests. Many other documents have been produced in conjunction with MEAP. Their common intent is to assist schools in improving their curricular/instructional programs. Two booklets, *Description of Test Content and Reporting Categories* and *Using the School Report*, are designed to assist school personnel in interpreting their results. Various summaries of statewide results present the interpretations of the assessment data by curriculum area specialists and the implications of these findings. Several recent publications report the findings of special components of MEAP involving open-ended and individual performance tests.

This report on science literacy is the latest of a series of special focus reports, each of which highlights MEAP results and/or current educational issues pertaining to a particular subject area. Its predecessors include: *Moving Geometry from the Back of the Book, Reading and Thinking: A New Framework for Comprehension,* and *Science in the Elementary Schools.* The intent of this publication is to examine the status of science literacy among Massachusetts students.

INTRODUCTION

In discussing the Goals of Education in Massachusetts, the Board of Education has stated:

> *Education should provide each learner with knowledge and understanding of mathematics and the sciences, encouraging exploration and discovery as well as the acquisition of facts.*
>
> *Schools should provide each student with a comprehensive program of science instruction, including biology and physical, earth, and space sciences. Students should understand the interrelationships among the sciences rather than learning subjects in isolation. The study of the sciences should build an awareness of the interdependence of all living things and the ways in which we can affect and improve our environment. It should also make students sensitive to the ethical issues raised by new developments in science and technology.*
>
> *Besides substantive knowledge, each student should derive from the study of mathematics and the sciences an understanding of process, ranging from methods of problem-solving to the scientific approach to inquiry and investigation. These subjects should be presented in a way that encourages exploration, experimentation, and critical thinking so as to hone the intellectual skills of every student.*

The purpose of this report is to examine how well students in Massachusetts are meeting these goals, as measured by the Massachusetts Educational Assessment Program (MEAP). The first section defines various levels of proficiency and then compares different groups within the student population in terms of the percentages attaining each level. The next section describes areas of relative strength and weakness within science of different groups. The report closes with a commentary on improving school science programs.

LEVELS OF SCIENCE PROFICIENCY IN MASSACHUSETTS

The school scores reported by the Massachusetts Educational Assessment Program have a mean of 1300 and a standard deviation of 100. Therefore, 68 percent of the school scores fall between 1200 and 1400. While the choice of a scale to which we transform schools' raw scores is somewhat arbitrary, the transformation still preserves the rank-ordering of and relative "distances" between schools. The advantages of converting scores to a common scale are numerous. It permits all kinds of comparisons across time, grades, and subject areas and, at the same time, accommodates the use of nonequivalent test forms. Hence, a testing program design such as MEAP's can provide the broad coverage of content areas appropriate for program evaluation.

One of the problems with the use of MEAP scaled scores is the mystery associated with the scores -- their failure to communicate just what students can and cannot do. The Assessment Program has addressed this issue in part by publishing statewide summaries which report the findings of curriculum specialists who meet to interpret individual test question results and discuss their implications. This report uses another approach to attaching meaning to the results. It explicitly defines several science proficiency levels and reports the percentages of various groups of students at or above the different levels.

DEFINITION OF PROFICIENCY LEVELS

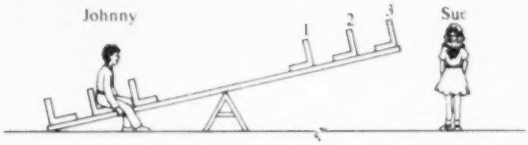
Five levels of science proficiency[1] are defined in the next few pages. They are defined in terms of the science knowledge and skills students possess when they have attained the various levels. Test questions representative of the levels are displayed to further clarify the competencies associated with the proficiency levels. The levels are specific points along a proficiency continuum, and the test questions displayed are particularly discriminating at those points. That is, students who have attained a particular level have a high likelihood of responding correctly to the associated test questions (probability greater than 60 percent), and students who have not reached that level are unlikely to respond correctly.

---

[1]The proficiency levels were defined by the National Assessment of Educational Progress (NAEP) through a combination of statistical methods and expert judgment. They were reported in *The Science Report Card*, Educational Testing Service, Princeton, New Jersey, 1988. The Massachusetts grade 8 and 12 scores were equated to the NAEP scale for the purposes of this report.

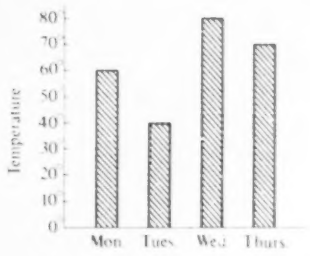
Level 1 -- Knows Everyday Science Facts

Students at this level know some general scientific facts of the type that could be learned from everyday experiences. They can read simple graphs, match distinguishing characteristics of animals, and predict the operation of familiar apparatus that work according to mechanical principles.



Look at the picture above. John weighs 90 pounds and Sue weighs 75 pounds. If Sue wants to make her end of the seesaw go down, should she sit at 1, or at 2, or at 3?

- o 1
- o 2
- ● 3



The graph above shows the high temperature on each day for four days. Which day was the hottest?

- o Monday
- o Tuesday
- ● Wednesday
- o Thursday

To which of the following animals is the wolf most closely related?

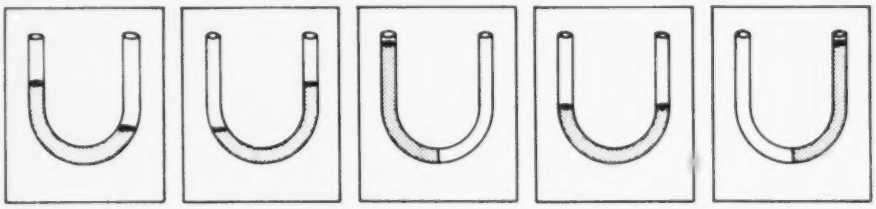
- o Buffalo
- o Deer
- ● Dog
- o Rabbit
- o Sheep
- o I don't know.

The reader should bear in mind that the proficiency levels defined in this report pertain to students of all ages. Thus, this first level is a very low level of proficiency easily reached by students in elementary school. The sample question about the seesaw is answerable by many young children based on recent personal experience. The graph question requires very low-level interpretation. And of course, young children spend a great deal of time in their early years identifying animals, thus making the third sample question fairly simple for them.

Level 2 -- Understands Simple Scientific Principles

Students at this level are developing some understanding of simple scientific principles, particularly in the Life Sciences. For example, they exhibit some rudimentary knowledge of the structure and function of plants and animals.

Some water is poured into the U-shaped glass tube shown above. Which picture below best shows how the water level will look? Fill in the oval under the picture you choose.



o I don't know.

What is the main function of the heart?

- ● To pump the blood to all parts of the body
- o To keep a person warm in winter by beating fast
- o To store extra blood until it is needed
- o To take waste food out of the blood

Why may you become ill after visiting a friend who is sick with the flu?

- o The room your friend was in was too warm.
- o You ate the same kind of food your friend ate.
- o You did not dress properly.
- ● The virus that causes the flu entered your body.

Although clearly higher level than the sample questions for Level 1, the questions above illustrate that Level 2 is still fairly elementary. Although the physical science question may require a student's intuitive understanding, a deeper understanding of the principle involved is not required, and it is unlikely that a student at Level 2 would have such an understanding. Both at home and in school, health practices and the spreading of germs are frequent topics of conversation. Furthermore, in the study of animal life, the heart is one of the first body parts considered. As the description of Level 2 above indicates, a student's knowledge of science at this level is rudimentary.

Level 3 -- Applies Basic Scientific Information

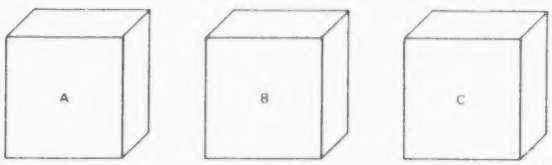
Students at this level can interpret data from simple tables and make inferences about the outcomes of experimental procedures. They exhibit knowledge and understanding of the Life Sciences, including familiarity with some aspects of animal behavior and of ecological relationships. These students also demonstrate some knowledge of basic information from the Physical Sciences.

Becky asked some friends in different grades how many books they read during the summer. Here is what Becky found.

Friend	Grade	# Books Read
Tom	6	5
Jane	5	5
Dan	2	2
Bob	2	1
Sue	1	0

Which of the following best tells what Becky found?

- o The students in the lower grades read as many books as the students in the upper grades.
- o The students read more books in the summer.
- o Becky asked one student from the 6th grade and two students from the 2nd grade how many books each read.
- • The students in the lower grades read fewer books than the students in the upper grades.
- o I don't know.



Blocks A, B and C are the same size. Blocks B and C float on water. Block A sinks to the bottom. Which one of the following do you know is TRUE?

- • Block A weighs more than block B.
- o Block B weighs more than block C.
- o Block C weighs more than block A.
- o Block B weighs more than block A.
- o I don't know.

With respect to the field mouse in the food web above, what is the fox considered?

- ● a predator
- o a prey
- o a producer
- o a decomposer

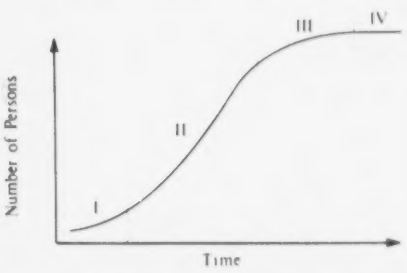
Ten plants were placed in sandy soil and ten others were placed in clay soil. Both groups of plants were kept at room temperature, given the same amount of water, and placed in a sunny room. This experiment tests the effect of

- o sunlight on plant growth.
- o temperature on plant growth.
- ● different soils on plant growth.
- o water on plant growth.

The Level 3 questions deal more with relationships of ideas or information than with isolated information. For example, the graph question requires the student to do more than simply locate or focus on one data point. Instead, the totality of information must be examined to determine the relationship between two variables. Other sample questions deal with predator-prey relationships and the relationship between buoyancy and weight (density actually, since the cubes are the same size). It is in the middle grades that students get involved in simple experiments involving the control of variables. The question on the plant experiment requires students to analyze an experimental design, recognizing variables that are controlled or manipulated.

Level 4 -- Analyzes Scientific Procedures and Data

Students at this level can evaluate the appropriateness of the design of an experiment. They have more detailed scientific knowledge, and the skill to apply their knowledge in interpreting information from text and graphs. These students also exhibit a growing understanding of principles from the Physical Sciences.



In the population growth curve above, in which interval is the population in equilibrium (the death rate equal to the birth rate)?

- o I
- o II
- o III
- • IV

Which of the following best explains why marine algae are most often restricted to the top 100 meters in the ocean?

- o They have no roots to anchor them to the ocean floor.
- • They are photosynthetic and can live only where there is light.
- o The pressure is too great for them to survive below 100 meters.
- o The temperature of the top 100 meters of the ocean is ideal for them.

The new product Super Plant Food has been advertised. Claims have been made that Super Plant Food will cause plants to grow to giant sizes. Directions on the label of this new product say: "Simply add 1 teaspoon of Super Plant Food powder to each gallon of water used to water your seeds or growing plants. Plants watered with Super Plant Food solution will grow faster and become twice as large as normal plants."

Suppose you wish to test scientifically the claims of the makers of Super Plant Food. Which of the following experiments would best test whether Super Plant Food helps the growth of bean plants?

- o Place 1 bean seed in each of two identical pots of soil. Water each pot with the same amount of Super Plant Food solution each day.
- o Plant 10 bean seeds in a pot of soil. Water with the same amount of Super Plant Food solution each day.
- • Plant 10 bean seeds of two identical pots of soil. Water one pot with a cup of Super Plant Food solution each day, and water the other pot with a cup of water each day.
- o Place 100 bean seeds on a sponge. Keep the sponge moistened with Super Plant Food solution.

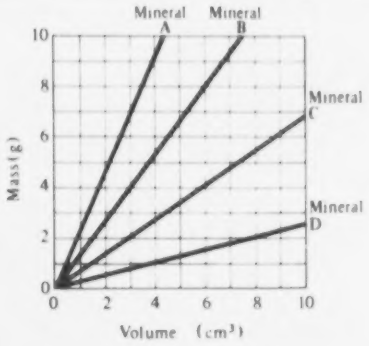
Which of the following is the best indication of an approaching storm?

- o A seismogram that is a straight line
- • A decrease in barometric pressure
- o A clearing sky after a cold front passes
- o A sudden drop in the humidity

The items above either involve more complex relationships than the sample questions for the lower proficiency level, or they require the student to recognize the relevance of and apply their knowledge of related concepts. For example, the graph question requires the student to realize that equilibrium means the number of persons would remain constant and that situation is reflected in a horizontal line on the graph. The question on marine algae has four plausible answers, so the student must recall and use his or her knowledge that algae are green plants to respond correctly. The question on experimental design requires the ***evaluation*** *of research designs, in contrast to the item characterizing Level 3, which required only the recognition of controlled and manipulated variables.*

Level 5 -- Integrates Specialized Scientific Information

Students at this level can infer relationships and draw conclusions using detailed scientific knowledge from the Physical Sciences, particularly Chemistry. They also can apply basic principles of genetics and interpret the societal implications of research in this field.



Water has a density of 1 gram per cubic centimeter. Which mineral(s) would float in water?

- o A only
- o D only
- o A and B only
- • C and D only

A female white rabbit and a male black rabbit mate and have a large number of baby rabbits. About half of the baby rabbits are black, and the other half are white. If black fur is the dominant color in rabbits, how can the appearance of white baby rabbits be explained?

- o The female rabbit has one gene for black fur and one gene for white fur.
- • The male rabbit has one gene for black fur and one gene for white fur.
- o The white baby rabbits received no genes for fur color from the father.
- o The white baby rabbits are a result of accidental mutations.

$2Na + S \rightarrow Na_2S$

The mass of 1.0 mole of sodium, Na, is 23.0 grams. The mass of 1.0 mole of sulfur is 32.1 grams. Approximately what mass of sodium is required to react completely with 32.1 grams of sulfur in the reaction above?

- o 11.5 grams
- o 23.0 grams
- o 32.0 grams
- • 46.0 grams

Recombinant DNA research has produced a variety of organisms with big economic potential. For which of the following reasons are concerned citizens hesitant to permit the use of these organisms outside of the laboratory?

- o Production of such organisms will involve the production of hazardous by-products.
- o Most scientific research is perceived to be dangerous.
- o The organisms could die outside of a laboratory environment.
- • The introduction of organisms new to the Earth could upset the ecological balance.

The brief description of the fifth level, above, seems to parallel the sample questions very well. The application of precise understanding of the concept of density is required by the graph question, and the question about the chemical equation requires the application of specific knowledge almost exclusively taught in high school chemistry. The same is true for the "rabbit" question and high school biology.

PROFICIENCY LEVELS OF DIFFERENT GROUPS

With proficiency levels now defined, it is reasonable to ask, "How do the scores achieved by Massachusetts students relate to these proficiency levels?" (Technical information on the equivalence of MEAP scores to scores on the National Assessment proficiency scale is provided in the Appendix.)

Table 1 shows the percentages of various subgroups at or above each level. The "growth" from grade 8 to grade 12, of course, is not surprising. Just over four-fifths of the eighth graders are at or above Level 3 (i.e., can apply basic scientific information) as compared to 95 percent of the twelfth graders. It should be noted that some of the questions characterizing the higher proficiency levels require knowledge of science content presented only in high school science courses. While there is a sizable difference in the percentage of students at the two grades at or above Level 4, that there are only 60 percent of the twelfth graders at or above Level 4 is disappointing. This means that over a third of the high school seniors are still operating at what might be considered a basic level in science.

TABLE 1
Percentages of Students at or above Five Proficiency Levels

	Level 1	Level 2	Level 3	Level 4	Level 5
Grade 8:					
All Students	99	98	82	26	2
Males	99	99	83	30	3
Females	99	99	80	21	2
Grade 12:					
All Students	100	99	95	60	14
Males	100	99	96	67	19
Females	100	99	95	55	9
Program:					
College Prep	100	100	98	72	20
General Program	100	99	92	44	6
Vocational-Technical	100	99	92	45	5
Highest Science:					
Biology	100	99	93	43	5
Chemistry	100	100	96	64	10
Physics	100	99	98	77	25

The differential performance of the sexes is evident at grade 8, where for every three male students there are at or above Level 4, there are only two female students. This difference is at a level (i.e., grade 8) at which there are no differences in the course-taking patterns of males and females. By grade 12, there are twice as many males as females at or above Level 5. As the discussion of the next table will suggest, course-taking differences do not explain the male/female difference in proficiency at grade 12.

Several other important points are supported by Table 1. Because college preparatory students always substantially outscore non-college-bound students, there is a tendency for educators to feel that they do not need to worry about the college-bound group. However, in terms of actual proficiency, over one-fourth of the college preparatory group, not having reached Level 4, are still only applying basic scientific information. Only one-fifth of the college prep students have attained Level 5.

Testing programs sometimes yield negative conclusions regarding the academic performance of students in vocational-technical programs. The breakdown of results in Table 1 sheds some new light on the performance of these students. While it is true that voc-tech students score below the statewide average, it is clear that voc-tech students score equally as well as non-college-bound students in a general academic program. Also, they are developing the skills of some trade at the same time. Of course, it is unfortunate that students in both the general and voc-tech programs are not attaining a much higher level of proficiency in science. Fewer than half of the students in either program have reached Level 4.

Table 1 also shows the proficiency levels of the groups of students whose highest-level science course is biology, chemistry, and physics. The data are consistent with our knowledge that most students (approximately four-fifths) take biology, while only the college preparatory students tend to take chemistry and/or physics. The students for whom biology is the highest-level science course taken are distributed across the different proficiency levels in the same way as students in general or voc-tech programs. They are undoubtedly the same students for the most part. Unfortunately, even students with coursework in chemistry and/or physics are deficient in terms of science proficiency. One-fourth to one-third do not attain Level 4. Very few reach Level 5.

Table 2 shows the MEAP science scaled scores for twelfth grade males and females broken down by school program and highest-level science course. Several things are apparent from the table. First, male students outscored female students by approximately 100 to 130 points depending on their school programs. The greatest difference was among college preparatory students. Second, female students do not tend to go as far in science coursework as male students. For every three male students whose highest-level science course is physics, there are only two female students. Finally, course backgrounds do not fully explain the male-female performance differences, since a 70-point difference remains for students who have the same backgrounds -- i.e., males and females whose highest level science is biology or chemistry or physics.

TABLE 2
MEAP Science Scaled Scores of Grade 12 Subgroups

School Program:	% Males	Scaled Score	% Females	Scaled Score
College Prep	55	1461	62	1337
General Program	27	1236	28	1117
Vocational-Technical	18	1207	9	1104
Highest Science:				
Biology	20	1205	27	1134
Chemistry	26	1338	33	1268
Physics	38	1477	21	1403

Note: The mean for all Grade 12 students is 1300, and the standard deviation of student scores is 341. Notice that the highest-science-course breakdown shown accounts for only 80 to 85 percent of the students. Other science courses (e.g., earth science, general science) than the three reported are the "highest" for the remaining students.

RELATIVE STRENGTHS AND WEAKNESSES WITHIN SCIENCE

SEX-RELATED DIFFERENCES

Differences between males and females in terms of overall science proficiency were discussed in a previous section. However, the male-female differences are better understood when one examines performance in subareas of science. Table 3 reveals important patterns of differences which should be acknowledged even if they are not entirely new information.

TABLE 3
MEAP Scores of Grade 8 and 12 Males and Females in Science Content Areas

Content Areas	State	Grade 8 Male	Grade 8 Female	Grade 12 Male	Grade 12 Female
Scientific Inquiry	1300	1330	1280	1330	1270
Life Science	1300	1340	1310	1320	1310
Earth/Space Science	1300	1380	1260	1400	1210
Physical Science	1300	1340	1240	1370	1180

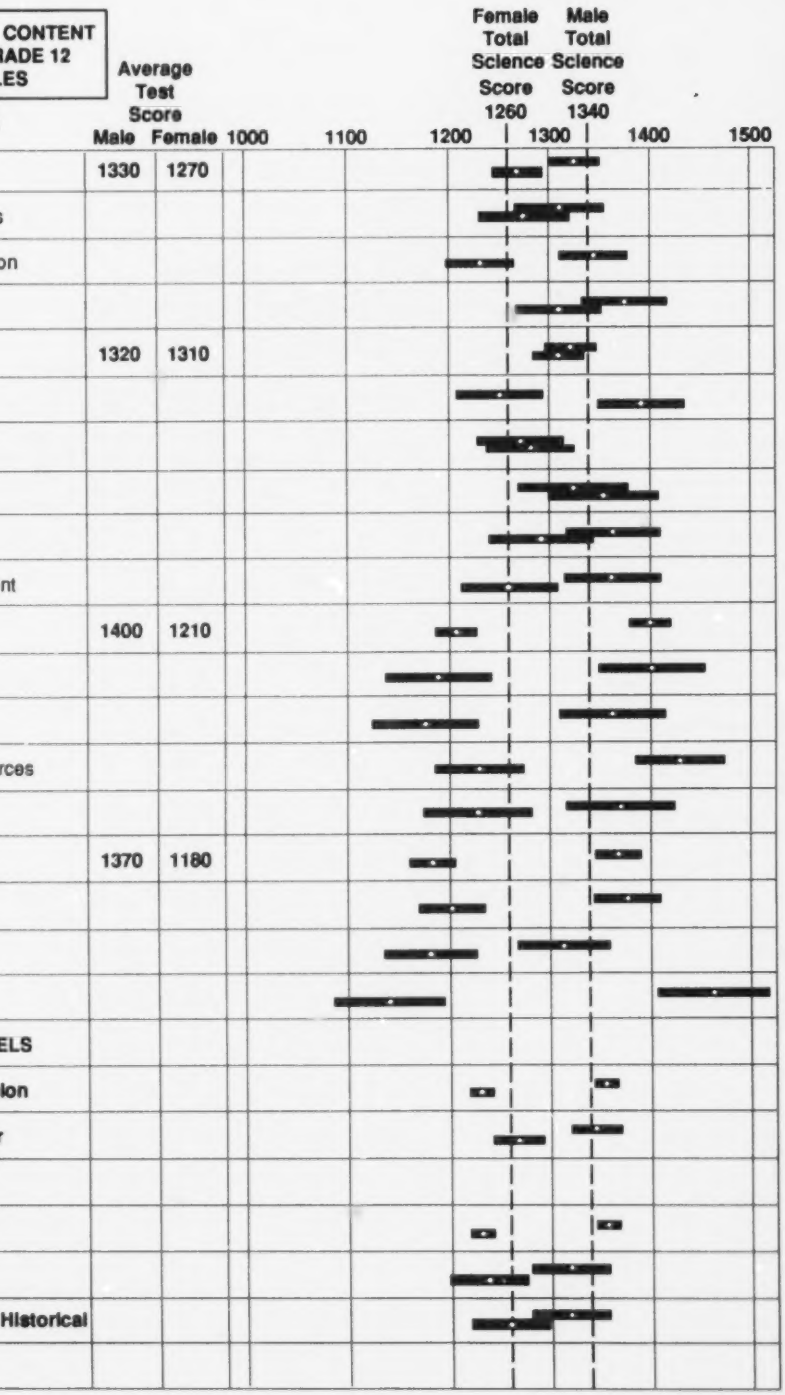
Note: These data are based on a sample of approximately 300 students from each of the four groups.

The table shows that by grade 8, although the sexes perform comparably in Scientific Inquiry and Life Science, there is already a substantial difference between male and female scores in Earth/Space Science and in Physical Science. Eighth grade males score higher than female students by a hundred or more points. By grade 12, the differences in these areas are almost two hundred points. The performance of the sexes is essentially the same in Life Science at grade 12, while senior males may have a slight edge in Scientific Inquiry.

The science areas are broken down even further in Exhibit 1. Displays similar to these are provided in the MEAP school reports to point out relative strengths and weaknesses of students within each school. In this case, the displays are based on samples of approximately 300 twelfth grade males and 300 twelfth grade females rather than on all the students in a school. Readily apparent in the exhibits are the findings from Table 3 -- i.e., a relative strength in Life Science and relative weaknesses in Earth/Space Science and Physical Science for females and relative strengths in these two latter areas for males. (The standard error bars for these areas, which represent plus or minus one standard error of measurement, lie completely to the right or left of the vertical dashed line corresponding to the group's overall science score.) "Zooming in" on the exhibits, one can see that the males are particularly strong in Force and Motion and particularly weak in Characteristics of Life while the reverse seems to be true for females (see Exhibit 1).

EXHIBIT 1. MEAP SCIENCE CONTENT AREA RESULTS FOR GRADE 12 MALES AND FEMALES

SCIENCE CONTENT AREAS	Average Test Score Male	Average Test Score Female
I. Scientific Inquiry	1330	1270
A. Designing Investigations		
B. Data Gathering/Reduction		
C. Data Interpretation		
II. Life Science	1320	1310
A. Characteristics of Life		
B. Health		
C. Animal Life		
D. Plant Life		
E. Ecology and Environment		
III. Earth/Space Science	1400	1210
A. Astronomy		
B. Meteorology		
C. Geology/Natural Resources		
D. Oceanography		
IV. Physical Science	1370	1180
A. Matter		
B. Energy		
C. Force and Motion		
COGNITIVE PROCESS LEVELS		
I. Knowledge/Comprehension		
II. Application/Higher Order		
CONTEXTS		
I. Scientific		
II. Personal		
III. Technological, Societal, Historical		

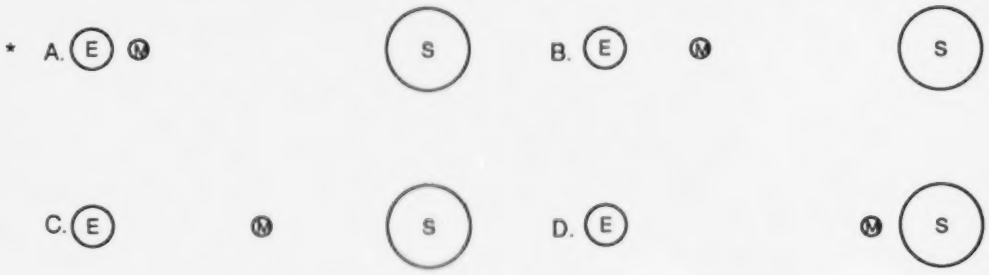


21

There were approximately 370 science test questions administered at grade 12. Looking at the percentages of students who correctly answered individual items, there were 30 questions on which males outperformed females by more than 15 percentage points. Of those, 19 were in Physical Science, 9 were in Earth/Space Science, 2 were in Life Science, and none were in Scientific Inquiry. Two questions with vastly different results for males and females are shown below in Exhibit 2.

% Correct Male: 69
% Correct Female: 42

Which of the following best illustrates the relative distance between the earth, moon and sun?



% Correct Male: 56
% Correct Female: 36

Which of the following best explains why the end of a spoon sticking out of a cup of hot water also gets hot?

A. The hot water causes a chemical reaction to take place in the spoon.
* B. The faster-moving molecules in the bottom of the spoon bump other molecules and get them moving faster, too.
C. The hot water heats the air surrounding the upper part of the spoon.
D. The hot water starts an electric current (a flow of electrons) up the handle of the spoon.

EXHIBIT 2. Grade 12 Male-Female Differences on Selected Earth/Space and Physical Science Questions

Grade 12 females outscored grade 12 males by 10 or more percentage points on 6 of the 370 test questions. Five of these questions were in Life Science, while the last was in Physical Science. Results on selected questions are shown in Exhibit 3.

% Correct Male: 80
% Correct Female: 91

Chemotherapy is sometimes used in the treatment of

A. diabetes.
* B. cancer.
C. tuberculosis.
D. pneumonia.

% Correct Male: 66
% Correct Female: 79

The menu below shows what Raul had for breakfast this morning.

pancakes
butter
maple syrup
sausage
milk

Which of the following should Raul eat with lunch to balance his diet?

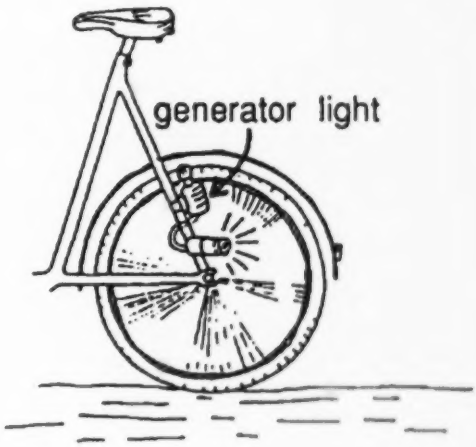
A. peanut butter sandwich
B. chicken noodle soup
* C. carrot sticks
D. grilled cheese sandwich

% Correct Male: 66
% Correct Female: 79

Which of the following is most beneficial in the prevention of gum disease?

A. fluoride and mouthwash
B. fluoride and brushing
C. mouthwash and flossing
* D. flossing and brushing

% Correct Male: 37
% Correct Female: 50



Maria has a generator light on her bicycle. She notices that when the light is being used it is harder to pedal at the same speed. How does the law of conservation of energy explain what Maria has noticed?

A. The generator light rubs against the wheel and slows the bicycle.
B. When energy from pedalling is transferred to the light, some of the energy is lost to the atmosphere.
* C. Some of the energy used to pedal the bicycle is changed into light and heat energy.
D. The amount of energy required to pedal at a certain speed is always the same; the light just makes it seem harder.

EXHIBIT 3. Grade 12 Male-Female Differences on Selected Questions

RESULTS BY SCHOOL PROGRAM

Table 4 reports the MEAP scaled scores for grade 12 students in college preparatory, general, and vocational-technical programs. Unlike the situation for the sexes, the performance for each of these groups appears to be comparable across the major areas of science. The table also shows the comparability of the performance of students in general programs and vocational-technical programs -- a finding consistent with the analysis of proficiency levels discussed in an earlier section.

TABLE 4
MEAP Scores of Grade 12 College Prep, General Program and Voc-Tech Students in Science Content Areas

Content Areas:	State	College Prep	General	Voc-Tech
Scientific Inquiry	1300	1420	1200	1190
Life Science	1300	1400	1230	1170
Earth/Space	1300	1420	1200	1240
Physical Science	1300	1420	1240	1210

Note: These data are based on a sample of approximately 300 students from each of the three groups.

Although displays showing relative strengths and weaknesses of students in the different programs within the science areas are not provided here as they were for males and females earlier, some discussion of them does merit attention. However, one must be careful in interpreting relative strengths and weaknesses to recognize the significance of the term "relative." For example, while college preparatory students have a relative weakness in the Life Sciences area of Health, their score in this area is still considerably higher than the corresponding scores of students in the general or voc-tech programs. The college preparatory students show particular strengths in Data Interpretation, Characteristics of Life, and Energy. This is consistent with the discussion of proficiency levels in an earlier section. Recall that the ability to interpret data, to apply the principles of genetics (which fall into the category of Characteristics of Life), and to understand many concepts of the Physical Sciences is indicative of higher levels of proficiency. A relative strength in Ecology and Environment exhibited by students in a general program may reflect greater participation in coursework in this area as opposed to the traditional academic sequence of Biology, then Chemistry, then Physics. The same situation may exist for voc-tech students in Earth/Space Sciences where these students show a relative strength. The content in these areas and any others stressing science-technology-society interactions is important for all students.

Science proficiency levels were examined not only for students in different school programs, but also for groupings of students based on "highest level of science taken." Again, individual test question results broken down for various groups can help us further understand where students stand in terms of science literacy. Exhibit 4 shows results on selected items broken down by sex and highest level of science. Perhaps the most important point to be made based on the data in the exhibit is that all is not well even for our most able students -- i.e., the students whose highest-level science course is physics. As it should be, the higher the level of science course taken, the higher the performance on the questions. However, the actual percentages of these students who answered correctly are disappointing. This is particularly true for the two Physical Science questions which address very basic concepts of conservation of matter and the gas laws. High norm-referenced scores based on a total population of students should not make us complacent about the capabilities of these more advanced students.

Exhibit 4 also reports item results for males and females. These results are representative of some of the general findings regarding sex-related differences discussed earlier. Recall that males did not have a substantial advantage over females in the area of Scientific Inquiry. The results on the data analysis question and the pendulum question certainly support this. The results on the other two questions in Exhibit 4 are also consistent with general findings about the poor performance of females in Physical Science compared to that of males. However, the data suggest more about these differences. Namely, differences in science course-taking do not explain sex-related differences found in statewide results. On these questions, as on many others, the sex-related performance differences remain even when looking at males and females with the same course backgrounds.

	% Correct		
Highest Course	Male	Female	All
Biology	61	66	64
Chemistry	64	76	72
Physics	73	73	73
All	69	71	

Philip has the same information on the 25 students in his grade in school:

NAME	SEX (M or F)	AGE (years)	BOOK CLUB MEMBERSHIP (yes or no)
Adams, Steven	M	13	yes
Archer, Beth	F	13	yes
Brown, Joe	M	14	no
Bruning, Jan	F	13	yes
Ca... Bon...	F		yes

To find out if girls or boys are more likely to belong to the book club, he wants to count the number of students in different groups and enter the totals in a table. Which table below should he use for his counts?

A.

NAME	BOOK CLUB YES	BOOK CLUB NO
Adams	x	
Archer	x	
Brown		x
Br...ing	x	

*B.

	BOOK CLUB YES	BOOK CLUB NO
MALE	9	16
FEMALE	19	6

C.

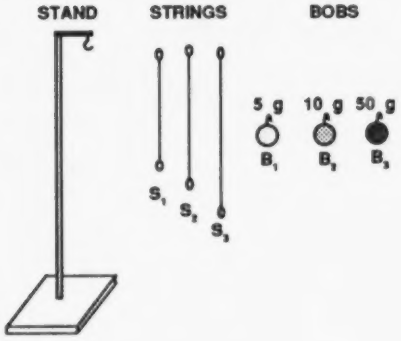
BOOK CLUB		SEX	
YES	NO	MALE	FEMALE
28	22	25	25

EXHIBIT 4. Grade 12 Group Differences on Selected Questions in Scientific Inquiry and Physical Science

Ralph believes that each of the following could affect the time it takes for a pendulum to make one complete swing:

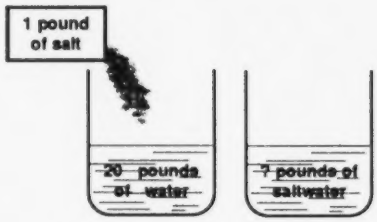
1. the length of the string
2. the weight of the bob
3. how far the bob is pulled.

In addition to the stand, which set of strings and bobs could Ralph use to test all three beliefs?



* A. S_1, S_2, B_1, and B_2
B. S_1, S_2, S_3, and B_1
C. S_3, B_1, B_2, and B_3
D. S_3 and B_3

% Correct			
Highest Course	Male	Female	All
Biology	26	21	24
Chem.	41	39	40
Physics	59	65	62
All	43	39	



One pound of salt is completely dissolved in twenty pounds of water. The resulting saltwater will weigh

A. nineteen pounds.
B. twenty pounds.
* C. twenty-one pounds.
D. The weight is unpredictable.

% Correct			
Highest Course	Male	Female	All
Biology	49	34	38
Chemistry	52	38	44
Physics	66	51	60
All	57	38	

EXHIBIT 4. Grade 12 Group Differences on Selected Questions in Scientific Inquiry and Physical Science (continued)

Which of the following contains the most molecules of water if the pressure is the same in each case?

A. a cubic foot of steam
* B. a cubic foot of liquid water
C. Both A and B contain the same number of molecules.

	% Correct		
Highest Course	Male	Female	All
Biology	47	23	32
Chemistry	35	36	36
Physics	60	41	54
All	51	32	

EXHIBIT 4: Grade 12 Group Differences on Selected Questions in Scientific Inquiry and Physical Science (continued)

COMMENTARY

When schools and even individual students receive test scores on norm-referenced, standardized achievement tests, they are only getting information on relative performance. Even without the score inflation problems haunting some of these measures these days, it is easy for a school or parent to be satisfied with results that suggest "we're doing OK relative to what everyone else is doing" when, in fact, actual performance may be far from satisfactory. By relating MEAP scores to well-defined proficiency levels and examining results on specific test questions, it becomes readily apparent that there is cause for concern regarding the knowledge and capabilities of students in science. The problem exists for all groups of students. Even the college-bound students, who most likely are the students taking high school chemistry and physics and who score well above statewide averages in science, do not perform at a level of proficiency one would expect for students likely to pursue science coursework beyond high school.

Consistent with the results of other studies, MEAP results show that female students perform substantially lower than male students in science, particularly in Earth/Space Science and Physical Science. Some educators have suggested that female students' lower performance in chemistry and physics may be related to the fact that these areas are more quantitative in nature, and women historically have shown poorer quantitative skills. However, the quantitative aspects of high school physical science do not require particularly high levels of math, and besides, male-female differences in mathematics performance are slight compared with those in the physical sciences. Furthermore, sex-related differences in these areas are quite pronounced even at the grade 8 level where math differences are minimal and course backgrounds identical. While many explanations of sex-related achievement differences have been proposed and investigated, it does seem clear that social factors, which ultimately affect motivation levels, do account for a significant portion. School personnel should examine the literature in the area to determine what steps they can take to minimize the problem in their schools.

The MEAP finding regarding vocational programs is important. Namely, the vocational students perform as well as the non-college-bound students in general academic programs. This matter is discussed below by Diane Paradis of the Assabet Valley Regional Vocational School District, who is a member of the MEAP Science Advisory Committee.

> *One educational area absent from criticism and critique [in terms of assessment tailored to specific programs] is vocational education. Voc-Ed is a positive and viable educational alternative to a traditional high school setting. The predominating goal of vocational education is to provide students with the opportunity and choice to acquire a marketable skill as well as a high school diploma. Most vocational students are employably trained upon graduation.*
>
> *Science education can and does play a major role in educating vocational students. Many of the vocational areas of study need the basics of science to complement these areas (e.g., Painting and Decorating -- the use of solvents, Home Carpentry -- thermal resistance of insulation, and Auto Mechanics -- the use of a hydraulic jack, a force transformer). Science in the classroom is presented using the approach that we use science in everyday living, in everyday situations, as well as in one's chosen career path. Science is a necessary supplement to vocational education and has been approached as such for years.*
>
> *Not all vocational students enter the work force upon graduation. A growing minority plan to further their education -- many in the same or related fields as their high school*

vocational training. With this fact in mind, the science curriculum must not be overlooked in the vocational educational setting. It can and is comparable and competitive with the traditional high school curriculum.

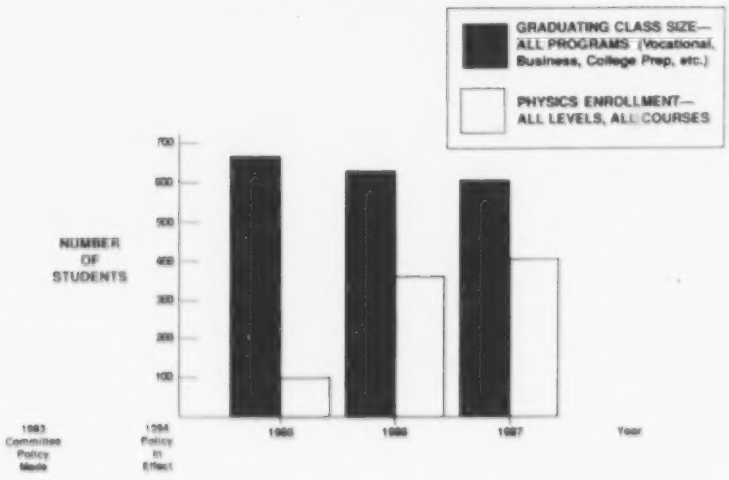
Another problem undoubtedly associated with low levels of science proficiency is the nature of high school chemistry and physics programs. The offerings in these areas tend to be quite academic and geared primarily for the college-bound students. This means that many students' exposure to the physical sciences is limited to that which occurs prior to high school. Henry Kaiser, former Science and Mathematics Coordinator in Pittsfield, describes successful efforts to increase enrollments in Physics below.

In the fall of 1983, the School Committee in Pittsfield, Massachusetts, began a series of public forums that considered action based on national educational issues highlighted in such reports as A Nation at Risk. By winter, 1984, policy decisions in science were presented to the administration in final form. Among the policy recommendations were several that addressed the level of science-course enrollments in the high schools.

Some directives were intended to encourage more students to study science in the high schools. Others were designed to make the study of physics, in particular, a common experience for most students. The recommendations taken together changed the grade level at which each of the science disciplines was traditionally offered, and prompted the development of more science electives to be offered in grade 12. Offering physics at grade 11 to most students and adding science electives of specific focus at grade 12 was the strategy used to improve science enrollments and keep a broad spectrum of students in a science sequence through four years of high school.

The project is still in transition, but physics enrollments have been markedly improving. Results are depicted in the graph below.

PHYSICS ENROLLMENT AFTER SCHOOL COMMITTEE RECOMMENDATION
PITTSFIELD, MASSACHUSETTS



Much of the concern regarding the science literacy of young Americans is tied to the requirement of an informed general citizenry. Dedham High School's Science Department Chairman, F. Paul Quatromoni, another member of the Science Advisory Committee, discusses science, technology, and society in terms of both instructional technology and course content:

Generally, the involvement of schools with science/technology/society issues continues to be minimal both in terms of utilization of appropriate support technology to facilitate the instructional process and in the development and implementation of curriculum materials to bring these issues to the attention of students.

Computers, present in increasing numbers, are often concentrated in computer science laboratories which makes more sense for instruction in programming and word-processing than for use in science applications. This may, in fact, deny access, both immediate and direct, to the majority of classroom teachers for whom they can provide the power to simulate, provide individualized remedial experiences, process laboratory data in real time, assist in data analysis, control equipment inventory, and track student achievement.

With respect to curriculum issues, student motivation appears to be a continuing and worsening problem at the same time many science courses, particularly at the secondary level, continue to focus on the more theoretical and abstract aspects of science. Surely, an adequate number of individually and locally relevant issues exist which could easily be related to content in most courses in order to illustrate the application of theory to practice, allow development of possible solutions, reduce the impact of emotionalism, and better serve both the schools and society as a whole. Examples might include water supply and distribution problems, sewage disposal, solid waste disposal, energy supply, conservation, and nuclear power. There are many sources of usable material presently existing. Failure to raise the level of scientific and technological literacy and to make these topics of real value and interest in the general population has both immediate and long-term consequences and implications.

If significantly raising the science proficiency levels of Massachusetts students is desired, local leadership in the endeavor is a necessity. Mary Corcoran, the Science Coordinator for the Winthrop Public Schools, is a past director of NSTA's Supervision Division, and another member of the Science Advisory Committee. She discusses the role of the science supervisor/specialist:

The position of science supervisor can be of real value to a school system that is seriously concerned about having a science program K-12 that is not only coordinated from school to school, but also grade to grade. The supervisor is responsible for working with the teachers to develop a curriculum that reflects the philosophy of the system and the needs of the students in the community. The supervisor works with the teachers and school principals to make available the materials and equipment, as well as inservice workshops, to ensure that the curriculum is actually implemented in every grade.

It is important that curriculum development be viewed as an on-going process. Because science instruction is in many aspects quite specialized, it is necessary to have a well-informed, knowledgeable specialist to advise on science process skills, conceptual objectives, instructional methods and materials, safe facilities, and media to support the program.

School administrators such as building principals are of necessity concerned with only one segment of the total curriculum K-12. The K-12 science supervisor serves as the liaison person and advocate for the total science program.

The limitations under which many dedicated science teachers are operating can be barriers to program improvement. The professional publications in science education are full of ideas for improving instruction. The professional groups have gone to great lengths to articulate just what science is important. But the truth of the matter is that implementing many of the changes needed to improve science programs require time and money. At a time when budgets, and hence funds for science programs, are being cut, we have to acknowledge that dissatisfaction with levels of science proficiency must be considered, at least in part, "getting what we are paying for." The need to make do with readily available materials and the need to train and assist teachers in doing this should make local leadership in science the highest priority and obtaining it a logical first step toward improving science programs in the Commonwealth.

APPENDIX: RELATING MEAP SCORES TO PROFICIENCY

Because a large number of questions used in the Massachusetts assessment were also used nationwide by the National Assessment of Educational Progress (NAEP), it was possible to equate the two measures - i.e., determine the equivalence of scores on the Massachusetts scale and the NAEP proficiency scale. Exhibit 5 shows the relationship between the five NAEP proficiency levels and the distributions of MEAP grade 8 and 12 student scaled scores. One can readily see from the exhibit that although the MEAP results were independently scaled producing a mean of 1300 at both grade 8 and 12, there is indeed a difference in the average proficiency levels at the two grades. One should also be aware that student scores were used in these analyses, not school scores which are much less spread out.

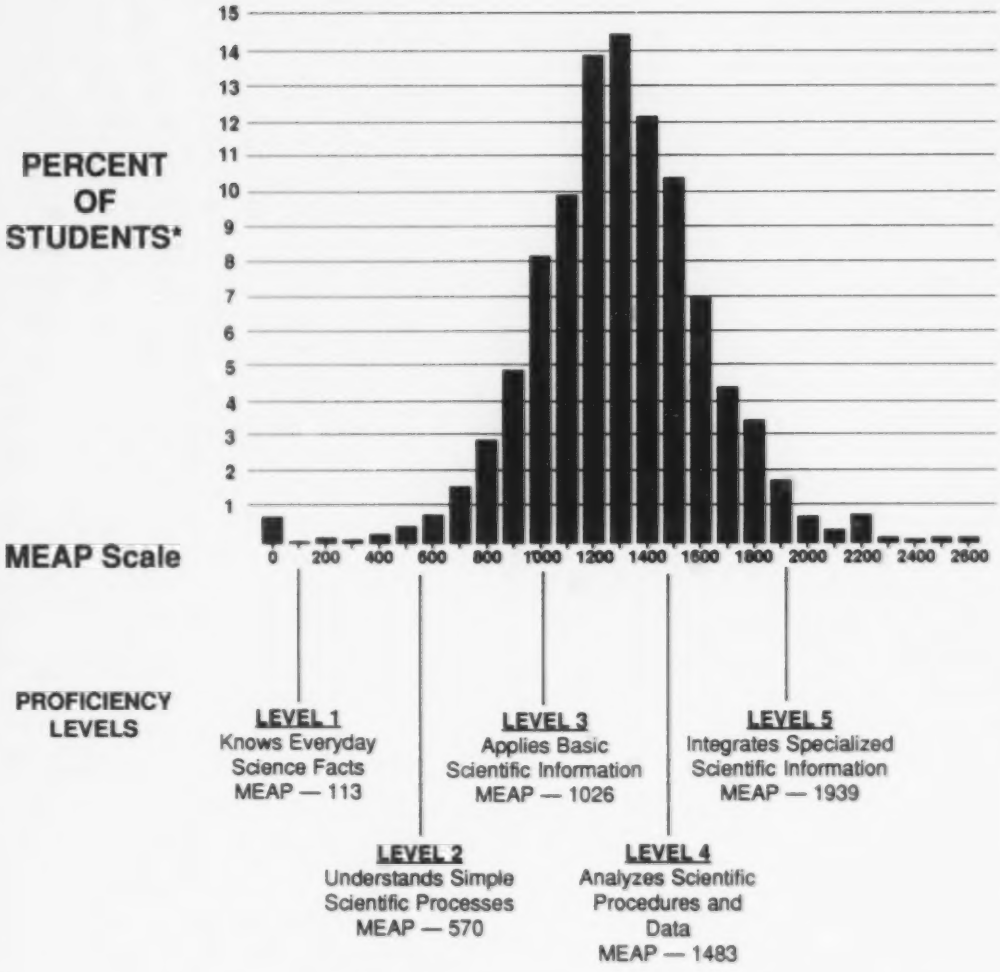


EXHIBIT 5A. Distribution of MEAP Student Scores, Grade 8

*Student scores were rounded to nearest 100 points

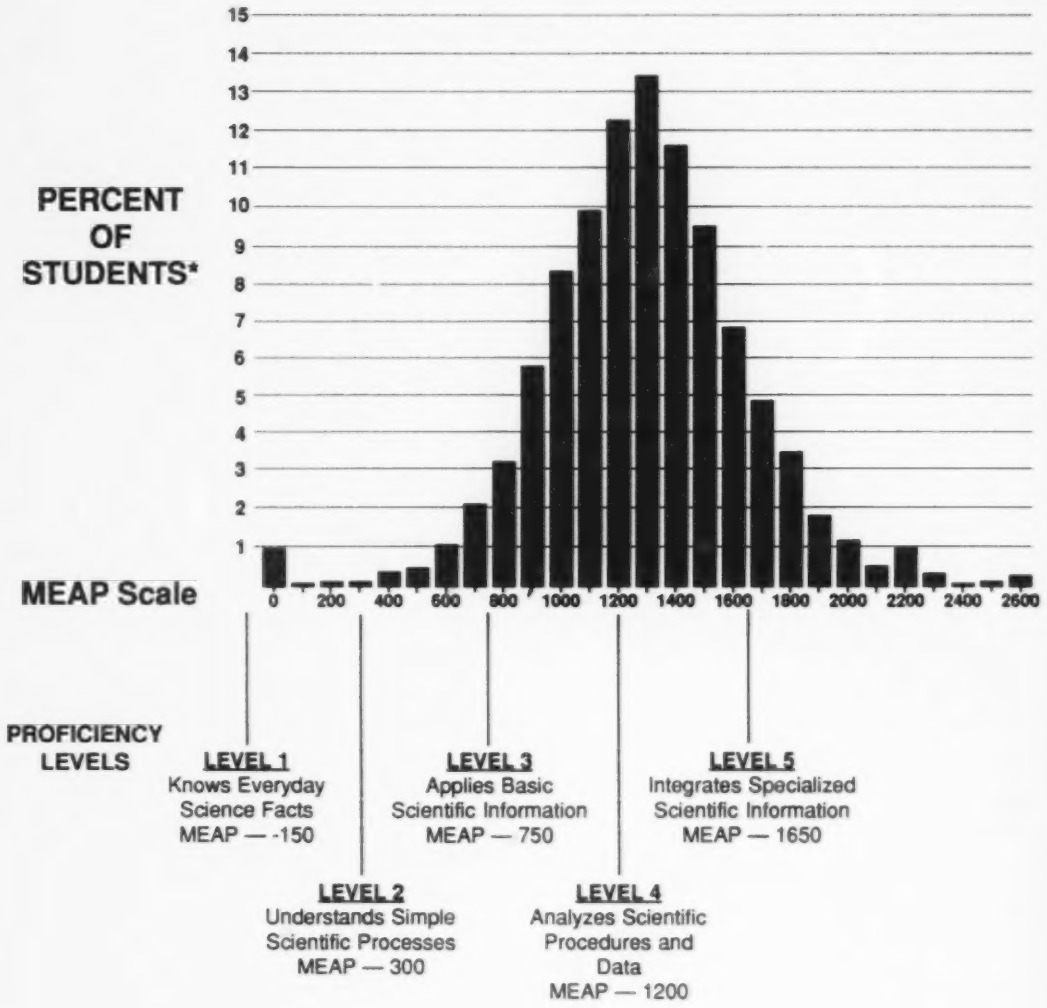


EXHIBIT 5B. Distribution of MEAP Student Scores, Grade 12

*Student scores were rounded to nearest 100 points.

MASSACHUSETTS DEPARTMENT OF EDUCATION

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Related publications about the Massachusetts Educational Assessment Program:

- *The Massachusetts Educational Assessment Program: 1988 Statewide Summary*
- *Using the School Report*
- *Reading and Thinking: A New Framework for Comprehension*
- *Science in the Elementary Schools*
- *Moving Geometry From the Back of the Book: A Report on Geometry and Measurement in the 1986 Assessment*
- *Social Studies Report*
- *On Their Own: Student Response to Open-Ended Tests in Reading*
- *On Their Own: Student Response to Open-Ended Tests in Mathematics*
- *On Their Own: Student Response to Open-Ended Tests in Science*
- *On Their Own: Student Response to Open-Ended Tests in Social Studies*